Domestic and International Experience With Spent Fuel Recycling

Domestic Experience

The DOE and its predecessor agencies operated several facilities that reprocessed spent fuel for the recovery of materials for defense, nuclear energy, and space programs. Plutonium was the main element recovered. Neptunium, americium, tritium, cesium, and strontium were also recovered on a significant scale. In excess of 100,000 metric tons of heavy metal (MTHM) were reprocessed at Hanford, Savannah River, and Idaho over a period of more than 40 years. Most of the spent fuel consisted of relatively small, metallic elements with a low burnup (usually less than 2,000 megawatt-days per metric ton of heavy metal (MWD/MTHM). The principal technology used was a solvent extraction technique known as the plutonium and uranium extraction (PUREX) process (and its variants). Pilot-scale facilities have used pyrochemical, metal, and eletrometallurgical technologies for reprocessing and recycling. DOE's high-level waste (HLW) is a result of these reprocessing activities.

There is limited domestic experience with commercial reprocessing and recycling. The Atomic Energy Commission (AEC) encouraged private organizations to become involved in reprocessing in the 1960s. The West Valley facility operated in the late 1960s and early 1970s, using the PUREX process. The facility nominally had a 300 MTHM/yr capacity and reprocessed about 650 MTHM. Approximately 60% of this material was metal fuel from the Hanford N-Reactor with a relatively low burnup. The remainder was oxide fuel—the highest burnup was around 20,000 MWD/MTHM. The facility also performed a demonstration on thorium spent fuel. West Valley operations generally met regulatory requirements, although exposures were not as low as reasonably achievable (ALARA) and radiation protection was a significant problem. The operator planned an expansion of West Valley to quadruple its capacity. Seismic issues were raised as part of the regulatory review and these issues increased the estimated costs by over an order of magnitude. Based on the increased costs and the potential for significant competition from other companies, the operator decided to cease operations.

GE designed and built a reprocessing facility in Morris, IL, utilizing a dry process for the main separations. The process relied on the volatility of uranium hexafluoride and was successfully demonstrated in the laboratory. Pre-operational testing at the constructed facility was not as successful and would have required major renovations. Given the projected costs and competitive reprocessing market, and increasing regulatory scrutiny (from the West Valley seismic reviews and the required safeguards), the operator decided not to pursue reprocessing at the facility. It is currently used as an independent spent fuel storage installation (ISFSI) for wet storage of commercial spent fuel.

The AGNS consortium constructed a third facility adjacent to the Savannah River Site in Barnwell, South Carolina. This facility utilized advanced PUREX technology for a planned capacity of 1,500 MTHM per year. The facility conducted uranium testing but never operated due to President Carter's decision to indefinitely defer commercial spent fuel reprocessing. The facility is currently undergoing decommissioning. Altogether, private industry invested approximately $2 billion in the Morris and AGNS facilities, however, neither facility began reprocessing operations.

Other companies were planning for reprocessing and recycle facilities. Exxon planned a 1,500 MTHM/yr facility at Oak Ridge, TN, and Westinghouse planned a Recycle Fuels Plant for approximately 600 MTHM/yr of mixed-oxide (MOX) fuel fabrication. These plans were shelved in the late 1970s and early 1980s.

All of these facilities were based upon a burnup of 30,000 MWD/MTHM typically used for spent fuel in the early 1970s. Utilities in the United States currently have about 45,000 MTHM in spent fuel, with an average burnup around 45,000 MWD/MTHM. Current spent nuclear fuel (SNF) discharges are around 55,000-60,000 MWD/MTHM burnup. Some pressurized water reactor (PWR) fuels are currently licensed for a 62,000 MWD/MTHM burnup at some sites. The maximum burnup currently licensed for a dry storage cask is 65,000 MWD/MTHM.

International Experience

Reprocessing is conducted on a significant scale in France, the United Kingdom, Japan, Russia, India, and China. Other countries (e.g., Belgium and Germany) have conducted pilot activities. As in the United States, reprocessing started in support of defense and nuclear energy programs, primarily using low-burnup metallic fuels. Subsequently, several large facilities have evolved providing commercial reprocessing and recycling services across national boundaries. The commercial reprocessing facilities are based on a nominal design capacity of 800 MTHM/yr and medium burnup (circa 40,000 MWD/MTHM) of oxide fuels, using optimized PUREX solvent extraction. To date, commercial operations have generally been economic and within regulatory requirements. Doses and discharges have decreased considerably from the late 1970s/early 1980s and now appear to have plateaued. Current trends indicate a decrease in reprocessing across national boundaries due to the startup of a new reprocessing plant in Japan, higher fuel burnups, more spent fuel storage (particularly dry storage), planned nuclear phaseouts in Germany and Sweden, limited new orders for reactors, and uncertain future plans. Separated materials (plutonium) are returned to the country of origin as MOX fuel. Commercial reprocessing facilities have indicated plans to return an amount of vitrified HLW equivalent to all the wastes generated from reprocessing a specific country's spent fuel back to the country of origin. Some vitrified HLW shipments have already been made to Belgium, Germany, and Japan.

France has two large reprocessing plants at the La Hague site, on its northern coast. The facilities are very large, occupying a space approximately 1.5 miles long by 0.75 mile wide, as shown in Figure 1. The UP-2 facility reprocesses domestic fuel for the French PWR fleet. Typical throughputs are 600-800 MTHM/yr. The French utility is intending to increase discharge burnups to approximately 50,000 MWD/MTHM. The UP-3 (sometimes called UP-3A) facility reprocesses spent fuel from PWRs and boiling-water reactors [BWRs]) for overseas customers, including Japan, Germany, and Belgium. The facility cost between $3 and 4 billion (1990 dollars) and was financed by international contracts. An additional, UP-3B facility was planned but not pursued due to the cancellation of many reactor orders in the 1980s and early 1990s.

UP-2 and UP-3A recover uranium and plutonium. Both are recycled—the plutonium in MOX fuel. Currently, the transuranics are sent with the fission products to onsite HLW vitrification facilities. Approximately 3 gigacuries of vitrified HLW canisters are in dry storage at the site (for comparison, the Hanford HLW tanks currently contain about 250 megacuries). Current French operations reduce the volume of material requiring a repository by approximately a factor of 6 compared to the estimated volume for direct disposal of the fuel.

Figure 1. La Hague Plants - Two 800 MTHM/yr plants

France operates a separate facility (MELOX, in southern France) for the manufacture of MOX fuel. MELOX has a nominal capacity of 200 MTHM/yr. In France, MOX fuel is irradiated to a burnup of 42,000 MWD/MTHM; the plan is to increase this burnup to approximately 50,000 (i.e., comparable to UO_2 fuel). MELOX also produces MOX fuel for overseas customers. France has reprocessed commercial spent MOX fuel through the UP-2 plant (primarily once through but there have been several tests with twice irradiated MOX fuel). France has conducted laboratory tests on americium and curium recycle, and has irradiated several assemblies.

French authorities and organizations have found reprocessing and MOX to be economic as waste management strategies but not as fuel management alternatives. French analyses have shown americium recycle to reduce repository dose impacts by a factor of about 40 and curium recycle to reduce dose impacts by two orders of magnitude. However, the need for a repository is not eliminated.

The United Kingdom (UK) operates several reprocessing facilities at Sellafield (Windscale) on the Northwest coast. These facilities reprocess low-burnup metallic fuels (approximately 6,000 MWD/MTHM from Magnox reactors) and medium-burnup oxide fuels (from advanced gas reactors [AGR] and light-water reactors [LWRs]). The B205 facility has a relatively large capacity and is used for the metallic spent fuel from Magnox reactors; Magnox reactors are approaching decommissioning, so the operations at B205 may cease in the next 10 years. The THORP facility reprocesses commercial oxide spent fuel. The facility has a nominal design capacity of 800 MTHM/yr and has been entirely financed by overseas sales contracts. The

THORP facility is the main facility of interest in the UK (the UK currently only has one LWR, and AGR fuel is now frequently stored dry). THORP has a vitrification plant that also processes HLW from Magnox spent fuel activities. Operationally, vitrification has experienced melter problems but the facility currently has some 1.5 gigacuries of vitrified HLW in dry storage. The overseas contracts at THORP expire around 2010 and there are no current plans to extend operation beyond that time.

The UK has approximately 100 tons of separated plutonium in storage from the reprocessing operations. The country is evaluating options for this material and is also reevaluating its energy options, including nuclear energy. Sellafield includes a separate MOX plant (SMP) for returning plutonium as MOX fuel to the country of origin. UK analyses of transuranic recycling revealed similar results to the French work. Only limited testing has been conducted to date.

Commercial reprocessing will begin soon at the Rokkasho-mura plant in Japan. The Rokkasho plant has a nominal design capacity of 800 MTHM/yr and was constructed at a cost exceeding $6 Billion (in 2005 dollars). The plant is undergoing uranium testing in 2006. It is designed for the production of a mixed uranium-plutonium product that can be used to produce MOX fuel for recycle in Japanese LWRs. Japan’s intention is to recycle materials as much as possible and, ultimately, to use fast neutron reactors both for energy and to manage HLW.